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Assessing the economic and environmental impacts of a public transport-based crowdshipping system

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Abstract

The paper estimates the willingness to act as a crowdshipper (supply) and to buy a crowdshipping service (demand) to get goods delivered/picked-up in a last mile B2C e-commerce situation and provide a preliminary evaluation of the economic and environmental impacts. Specifically, it considers an environmental-friendly crowdshipping based on the use of the mass transit network of the city where parcels customers/crowdshippers pick-up/drop-off goods in automated parcel lockers located either inside the transit stations or in the surroundings. Crowdshippers are passengers that would use the transit network anyhow for other motivations (e.g. home-to-work trips). The paper rests on an extensive stated preference survey. The hypothetical scenarios used to acquire both demand ("customers") and supply ("crowdshippers") preferences make use of the most relevant attributes emerging form a preliminary investigation performed in the study context. The paper uses discrete choice models to estimate willingness to pay measures representing the most reliable measure of agents' likely behaviour. The investigation refers to the city of Rome and considers the metro as the main transit system. The results are useful in understanding and quantifying the potential of this freight transport strategy for e-commerce in an urban context. It provides local policy makers with a good knowledge base for its future development and for estimating the likely impact the system could have on emissions.

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Keywords: Crowdlogistics; Urban freight transport; E-commerce; On demand economy; Discrete choice modeling

1. Introduction

Urbanization and e-commerce are two fast-rising trends that make city logistics solutions even more challenging. There are several urban freight transport policies that could be adopted to find a good balance between positive impacts

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on accessibility and economic development and negative externalities in terms of congestion and polluting emissions (e.g. NCFRP, 2015). Crowdshipping is one of the most promising solutions that foresees an integration of passenger and freight mobility. In line with sharing economy, it implies delivering goods using the crowd making use of modern information communication technologies (McKinnon, 2016).

This work aims at understanding and evaluating the environmental and economic impacts of a crowdshipping platform in urban areas. This goods distribution system produces a positive impact on the environment by exploiting unused transport capacity. Crowdshipping could be beneficial both for the final consumer, as it could produce faster and cheaper deliveries, and for the community at large by reducing road congestion and emissions.

The specific type of crowdshipping this paper investigates is linked to e-commerce in its B2C manifestation and is based on crowdshippers using public transportation. Moreover, the analysis focuses on the last mile of the delivery chain in the urban area of Rome. The last leg of delivery is also the most appropriate part of the e-commerce chain where a crowdshipping scheme might prove applicable and useful (Le and Ukkusuri 2018, Winkenbach and Janjevic 2018). In fact, most of the goods are small in size and light in weight, allowing the ‘crowd’ of commuters to act as a last-mile vector.

The motivations for investigating crowdshipping in the city of Rome include the following: large extension, complex transit network, congested road network. This focus might generate a question concerning the generalizability of the results to similar urban contexts.

Trust, safety, and privacy concerns are listed as shortcomings of crowdshipping. For these reasons, the service has yet to reach its maturity (Punel et al. 2017). However, the research presented in this paper underlines the need to forecast the economic and environmental sustainability of this growing sharing system.

The paper is structured as follows. Section 2 describes the methodological approach used to preliminary assess economic and environmental sustainability, while section 3 reports the results obtained related to the implementation of a crowdshipping service in Rome. Section 4 concludes illustrating future research.

2. Methodology

This section illustrates data, methods and assumptions characterizing the approach proposed. Quantifying and monetizing the benefits for the community as well as service costs is fundamental to calculate the economic and environmental sustainability of a crowdshipping platform. The methodological scheme is reported in Figure 1.

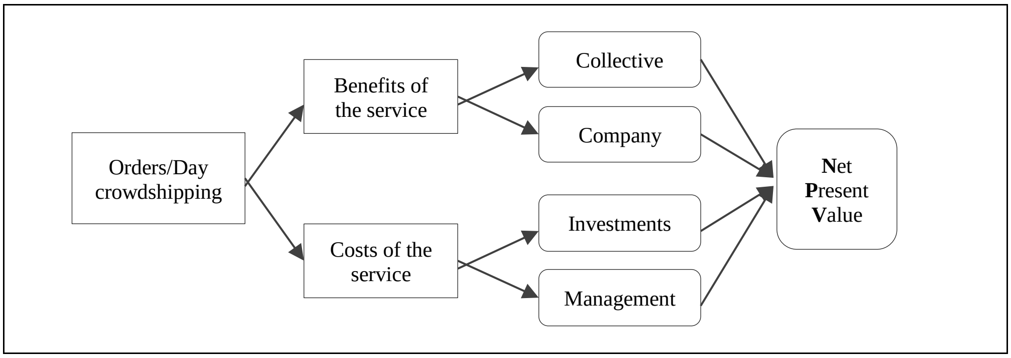


Figure 1: Methodological scheme

The first step is the estimation of the number of daily orders linked to a crowdshipping service. The willingness to act as a crowdshipper (supply) and to get goods delivered/picked-up with a crowdshipping system (demand) is estimated using discrete choice models based on an extensive stated preference survey. Starting from those results, a scenario analysis is performed assuming different service specifications and also considering other factors such as: (i) e-commerce demand growth trends; (ii) socio-demographic evolution; (iii) metropolitan network expansion. The paper considers a time frame up to 2025 based on the Sustainable Urban Mobility Plan of the city of Rome (PUMS, Rome mobility services, 2016).

Individual orders are then transformed in vehicle equivalent units, i.e. the number of commercial vehicles needed to transport a certain quantity of orders, setting respectively the average packing volume and average load capacity of a light commercial vehicle.

The load capacity has been set at 8 cubic meters in compliance with the vehicle fleets of the major national couriers operating in Rome. However, since Nuzzolo et al. 2010 suggest that the load factor in Rome is about 50% of the transportable volume, we assume that the load value to be 4 cubic meters. The average dimensions of the parcel have been set equal to 40x30x30cm. This size is consistent both with the crowd (couriers) and with the typical e-commerce orders (Regattieri et al., 2014).

The paper uses the COPERT (COmputer Programme to calculate Emission from Road Traffic) calculation model to estimate the environmental benefits due to lower emissions of air pollutants. The European Environmental Agency (EEA) uses the COPERT methodology for drafting reports on the state of the environment. The emission of a vehicle i is calculated as the sum of three contributions:

$$E_i = E_{hot,i} + E_{cold,i} + E_{vap,i}$$

where:

$E_{hot,i}$: $hot\ emissions,$ generated by the engine at operating temperature;

$E_{cold,i}$: $cold\ emissions,$ generated during the engine warm-up phase;

$E_{vap,i}$: $evaporative\ emissions,$ composed exclusively by NMVOC (Non-Methane Volatile Organic Compound).

Data on traffic conditions are particularly important model inputs. Vehicle category classifications in 2017 in Rome serve to order to identify vehicle fleet characteristics for scenario comparisons purposes.

Table 1. Circulating fleet data

EURO Class	Vehicle category (EURO)*		km/year **	km cumulative***
	LCV - Petrol	LCV - Diesel		
0	0.8%	11.7%	4'950.00	608'319.69
1	0.6%	7.9%	7'920.00	368'979.34
2	1.0%	14.3%	14'548.00	272'132.62
3	1.4%	19.0%	19'000.00	223'531.25
4	1.4%	19.8%	28'726.00	190'067.89
5	1.1%	15.3%	30'193.00	138'635.23
6	0.4%	5.4%	36'000.00	36'125.92

* Circulating fleet in Rome (LCV), 2017. Open Data Ministero delle infrastrutture e dei trasporti
** ACI, 2000-2015 and ISPRA, 2015
*** Ricardo-AEA (2014)

For each scenario and for each reference year, the emissions saved were estimated assuming that a certain share of orders, and therefore equivalent vehicles, are transferred to couriers (crowd-shippers) using the underground to commute to work. The reductions in environmental externalities were subsequently transformed, using unit costs, in monetary values so to calculate the ensuing economic benefits.

Private company profits are also estimated. In line with other crowdshipping services, already operating in the market, we assume that crowdshipping platform retains a 10% margin on the fee paid to the crowd-shippers for the service produced. In other words, if the traveler-courier fee is € 1, the platform earns € 0.10 and the final consumer pays the delivery service € 1.10. Besides, the shipping cost for the detour the crowd-shipper has to perform could also be added to the final price.

The service costs, divided into investment costs and management costs, are assessed on the base of each scenario number of orders /days.

Investment costs refer to the purchase of APLs and the creation of an IT platform to manage the service. The APL are dimensioned based on the daily demand and assuming each order is collected the same day. Purchasing and management costs have been derived from different sources, including articles and manufacturers' brochures and websites. The average purchase cost used in this study ranges from € 11'000 for a block of 50 lockers up to € 60'000 for one of 400. As for the cost of the IT platform, the paper uses a flat-rate cost of € 20'000.

Operating costs include APLs maintenance and software updates ones. The paper assumes a € 30 / unit-year for the former and a flat annual rate of € 5'000 for the latter. Moreover, from a mid-term perspective, it seems fair to assume that APLs management costs decrease in line with technological improvements and economies of scale. This motivates setting a € 3 / unit-year reduction for lockers' maintenance.

3. Results

Two stated preference surveys were administered in Rome, acquiring around 240 respondents each, to investigate crowdshipping demand and supply (for more details, please see Serafini et al., 2018).

As it is for the supply-side, the attributes characterizing the hypothetical alternatives are: remuneration (1€, 3€), delivery booking (real-time, off-line), automatic parcel lockers (APL) location (inside, outside metro stations), and bank crediting modes (single delivery, every 5 deliveries). In the case of demand-side, the chosen alternatives are: shipping cost (typical, lower than typical), shipping time (typical, lower than typical), parcel tracking availability (yes, no), and delivery schedule date/time flexibility (yes, no).

Table 2 reports the results of the multinomial logit models estimated for both the demand and supply side. The models fit well the data and the coefficients are all statistically significant and have the expected signs. The variable age is included in the "no choice" option together with the alternative-specific constant (ASC). Age coefficient is positive showing that older people are less interested in working as crowdshippers or in using a crowdshipping service.

Table 2. Multinomial logit model results – demand and supply

Demand			**Supply**		
Attributes	**Coeff. (β)**	**T-test**	**Attributes**	**Coeff. (β)**	**T-test**
Age	0.0905	7.65	Age	0.0473	4.25
Shipping fees (lower)	0.6750	6.76	APL location (inside metro stations)	0.5940	8.42
Shipping time (lower)	0.5870	6.65	Remuneration (3 €)	0.4890	8.02
Parcel tracking (yes)	0.6980	7.38	Delivery booking (real-time)	0.3350	4.90
Delivery date/time flexibility (yes)	0.7860	8.87	Bank credit mode (single delivery)	0.5330	7.64
"no choice" [ASC]	-5.2300	-8.90	"no choice" [ASC]	-3.390	-7.03
Adjusted rho-square: 0.299			*Adjusted rho-square: 0.281*		

According to the results obtained, three demand scenarios have been considered (Table 3). The "base scenario" is the one assuming the most likely configuration of the possible crowdshipping service. The base scenario is compared with others called 'favorable' (with lower shipping fees) and 'unfavorable' (with no flexibility in delivery date and time schedule) respectively.

The probability of choosing such a service ranges from 16% to 66%.

The number of potential daily orders are reported considering a catchment area of 800m radius for each metro station stop and an e-shopping rate of 0.0262 orders/day per inhabitant, both for the current state and the year 2025. E-shopping rate is calculated taking into account the percentage of the population making at least one online purchase, the percentage of orders requiring a physical shipment and the annual average frequency of online purchase.

Table 3. Estimation of potential demand for crowd-shipping by public transport (current state - year 2025)

Demand SCENARIOS	Crowdshipping service adoption probability	Potential demand - current state - [orders/day]	Potential demand - year 2025 - [orders/day]
Favourable	66.10%	14'100	29'540
Base	59.70%	12'730	26'680
Unfavorable	16.40%	3'500	7'330

Estimating the number of potential crowdshippers per day according to different scenarios one discovers that the supply always exceeds the demand thus testifying the feasibility of the solution investigated. This might depend on the following factors: (1) e-commerce in Italy is not as developed as in other European countries; (2) many consumers are not willing to adopt crowdshipping mainly due to trust-related, reliability, privacy and withdrawal convenience issues.

Below we report the environmental-related benefits for the 2017-2025 period, based on the above assumptions, for the implementation of a crowdshipping service in Rome. The paper uses COPERT to quantification the reductions in emissions for particulate, nitric oxide, carbon monoxide and carbon dioxide. One can, on average, save 239 kg of particulates per year, with an oscillation between 66 kg and 265 kg. Nitrogen oxide will, on average, be reduced by 3.76 tons per year with a variation between 1.04 and 4.17 tons. When it comes to carbon monoxide, the reduction is of 2.24 tons per year with a minimum of 0.58 and a maximum of 2.49 tons. Finally, for carbon dioxide the emission avoided are 1'098 tons per year with extreme values reaching 304 and 1'215 tons.

The growth of e-commerce implies that the number of equivalent vehicles replaced by crowdshipping will increase with a consequent upsurge of emissions saved.

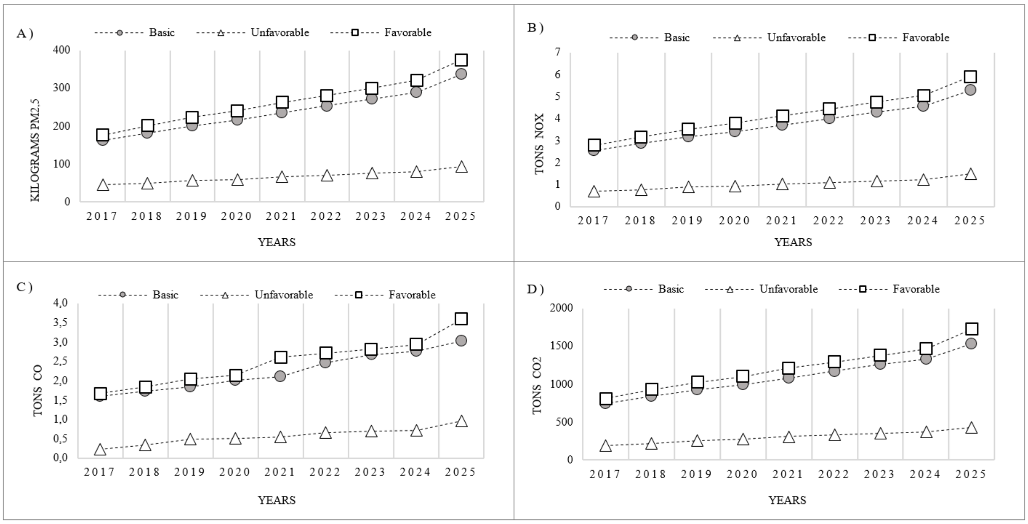


Figure 2: Estimation of pollution emissions: particulate (a), nitric oxide (b), carbon monoxide (c), carbon dioxide (d)

Once evaluated the reduction in emissions and vehicle-kilometers, one has to transform these values in monetary terms so to monetize traffic externalities related to local, global, acoustic pollution, and accident risk. The paper uses Ricardo-AEA (2014) and Litman (2011) unit costs to perform this task.

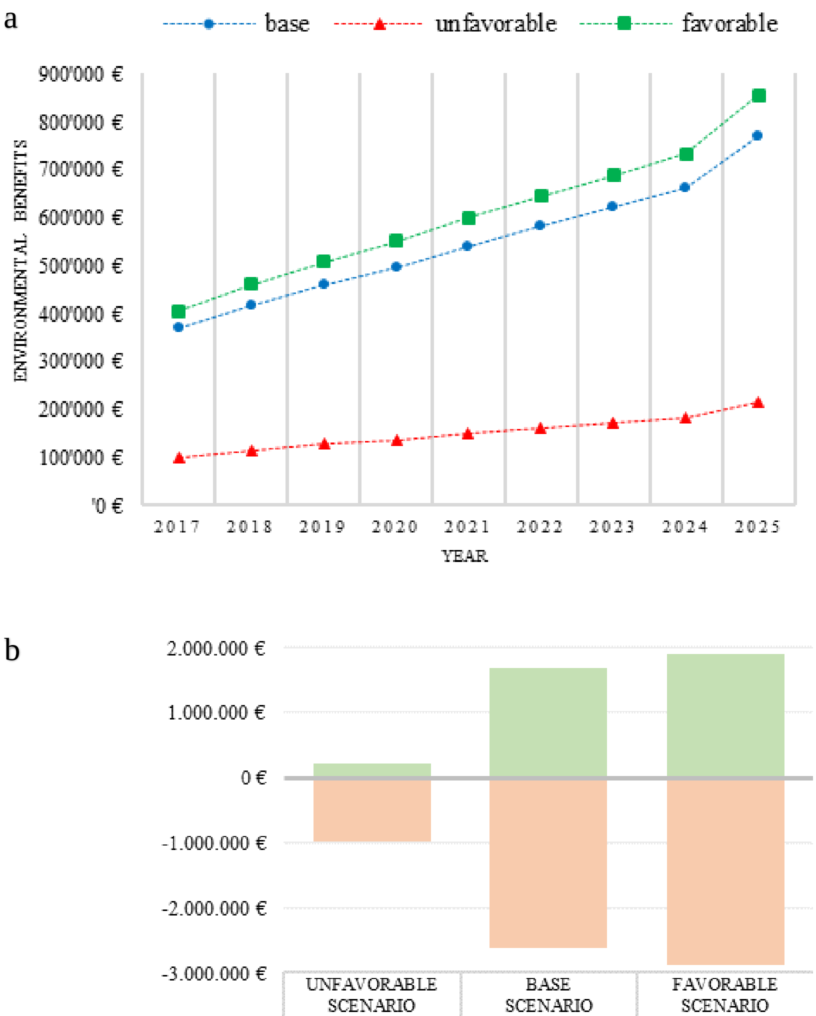
The last part of the paper reports the Cost-Benefit Analysis (CBA) calculations for the implementation of a crowdshipping service in Rome. This is the most frequently used analysis for evaluating projects of collective interest and represents a useful tool for policy maker. One can summarize the key elements of the CBA analysis as follows: (1) investment costs; (2) operating costs; (3) cash inflows.

The Net Present Value (NPV) is a synthetic index to express CBA results. It measures the difference between the present value of cash inflows and that of outflows over a given period of time:

$$NPV = \sum_{t=0}^{n=8} \frac{S_t}{(1+i)^t}$$

where:

S_t is the net cash flow at time t, i is the discount rate, and t the time of the cash flow. This study assumes a 3% social discount rate as set by the European Union (MIT, 2016).



	UNFAVORABLE SCENARIO	BASE SCENARIO	FAVORABLE SCENARIO
NPV with environmental benefits	208'779 €	1682'241 €	1898'610 €
NPV without environmental benefits	-978'622 €	-2627'591 €	-2871'319 €

Figure 3: (a) Estimation of monetized collective benefits. (b) Net Present Value

The NPV obtained without considering public benefits is negative underlining that costs prevail over revenues for the platform operator. However, considering that environmental benefits impact on society as a whole, it is reasonable to suppose that their economic value can be converted into public incentives and, therefore, be deducted from the total costs of the platform. Following this assumption, the NPV takes a positive sign indicating the economic as well as environmental sustainability of the platform during the 8 years considered.

The biggest challenge policy makers have to face with is the redistribution of costs and benefits among stakeholders. In particular, policy makers should provide the subsidies needed to cover platform costs due to the collective benefits it would produce.

In fact, as shown in Figure 4, if the collective benefits converted into subsides for crowdshipping operators are less than 100%, then a reduction in net income occurs compromising the economic sustainability of the platform. A 25% reduction in subsidies implies a non-sustainability should an "unfavorable scenario" materialize. A 50% subsidies reduction makes no scenario economically sustainable.

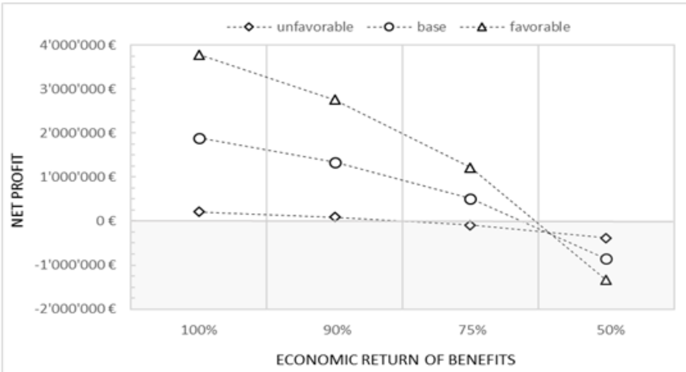


Figure 4: Net income as subsidies change

4. Conclusions

Cities need new logistics solutions dealing with the requirements of the on demand economy. Crowdshipping is a promising solution for sustainable urban freight distribution.

This paper provides an assessment of economic and environmental impacts of a "green" crowdshipping based on a stakeholder behavioural analysis focusing on both demand and supply sides. Results suggest that implementing such a crowdshipping service in Rome produces a total savings of 239 kg of particulates per year. Moreover, considering alternative scenarios, the economic sustainability is reached only with public incentives justified by the environmental benefits to the society that such a system is able to produce.

Future research endeavors will focus on providing: (i) a more detailed environmental evaluation using micro-simulation modelling both accounting for realistic traffic conditions and availability of commercial bays and comparing traditional versus public transport-based crowdshipping; (ii) an in-depth analysis of both technical requirements (e.g. parcel lockers location and size) and the needed coordination between shippers, logistics operators and crowdshipping platform providers; (iii) a comprehensive analysis investigating, under a multidisciplinary approach, the wide range of critical elements (e.g. economic, legal, social, psychological issues) that hinder the adoption of a successful business model.

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